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A COMPUTER AIDED DIAGNOSIS TOOL FOR BRAIN MORPHOMETERY ANALYSIS USING MAGNETIC RESONANCE IMAGES

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Abstract: From the ages, images are considered as most important medium of information transfer. Such images have to be studied and information from them is extracted for further processing, this is an important feature of Machine learning. The radiologists use x-rays, MRIs etc., and from these types of images, the work required commonality, time for processing or consumption and hence demand automation. They usually don't require the automation for detection and processing but rather use for documentation and quantification. Here we have devised a tool for automated segmentation of regions of brain from MRI. The devised tool is capable of quantifying the segmented regions and provides other types of analysis in order to aid the radiologist in detection and documentation. The three different segmentation approaches lime K means, Fuzzy C Means Clustering (FCM) and Watershed segmentation are studied for their applicable suitability. The results of the segmentation are evaluated using different evaluation parameters. A Graphical User Interface (GUI) which is designed as part of the tool is also presented.

1. Introduction

According to assorted community based surveys, pervasiveness of mental disorders in India is 6-7% for common or intimate mental disorders and 1-2% for severe mental disorders. It is observed that in India the rate of psychiatric disorders in children aged between 4 to 16 years is about 12% and nearly $1/3^{rd}$ of such population is less than 14 years of age. With such a magnitude of mental disorders it turn out to be necessary to promote mental health services for the well being of general population, in addition to providence of treatment for mental illnesses. Treatment for severe mental disorders is approximately 50% and in case of Common Mental Disorders it is over 90% [1]. Effective diagnostic and treatment modalities are the need of the hour in tackling this huge menace. At present multiple imaging modalities are available to image specific organs or region of the human body. Coupled with exponential growth in the processing power of computing system and the enhancement in the capacity of storage elements, the use of medical images has breached many boundaries. One of the important applications of medical imaging is analysis of the brain images. Very specifically computational neuro anatomy which includes

automated analysis of neuro anatomical structures using different imaging procedures has become fore front of medical image processing.

Human brain is considered as the most complex organ in the human body. Human brain is reception. responsible for processing. transmission, perception and interpretation of Brain along with spinal cord information. constitutes the central nervous system. The brain can be classified in different ways into different anatomical regions. One of the most common classifications is to divide the brain into three regions namely (1) Fore brain (2) Mid brain and (3) Hind brain. The anatomical complexity of human brain makes the process of imaging and analyzing very difficult. In spite of huge advancements in medical imaging procedures, accurate segmentation and classification of brain abnormalities remains a challenging and daunting task.

Anatomical segmentation of structures of human brain forms the preliminary step towards computer aided diagnosis and therapy. Medical image segmentation being a complex and challenging task needs precise methods for identifying and segmenting different regions of

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interest. The literature presents a gamut of MRI segmentation approaches, most of the approaches fall under thresholding, region growing and clustering. In the case of brain image it is important to know that the distribution of tissue intensities is not uniform and it makes process of determining threshold very difficult. This factor makes the thresholding methods restricted and they have to be combined with other methods.

Of all the different types of methods available, clustering methods appear to be most popular and successful methods for medical image segmentation. These methods include FCM, kmeans expectation maximization, watershed algorithms etc... This paper explains a CAD systems specifically designed for the purpose of segmentation of brain MRI. Three different segmentation procedures K like means segmentation, Watershed segmentation and Fuzzy segmentation employed means are С for segmenting the images and the results of segmentation studied and observed .The designed CAD tool also has multiple functions that will help the radiologist in providing a reliable secondary opinion.

2. Magnetic Resonance Imaging for Brain studies

Magnetic resonance imaging (MRI) is an important diagnostic imaging technique for the early detection of abnormal changes in tissues and organs. It possesses good contrast resolution for different tissues and has advantages over computerized tomography (CT) for brain studies due to its superior contrast properties [2]. Therefore, the majority of research in medical image segmentation concerns MR images.

The typical advantages of MRI include

- 1. Unlike CT, SPECT and PET, MRI uses non ionizing radiations and very specifically
 - Preferred for brain imaging.
- 2. The contrast resolution provided by MRI is much higher than the other imaging modalities.
- 3. In terms of spatial resolution also magnetic resonance images are

superior in providing the localization of brain tumors.

4. Magnetic resonance images are capable of extracting functional as well as anatomical information of tumors during the same scan.

Magnetic resonance imaging being the most widely used imaging procedure is dynamic and flexible technology. In the case of magnetic resonance imaging variable image contrast can be achieved by using different pulse sequences and by altering the imaging parameters corresponding to the longitudinal relaxation time (T1) and the transverse relaxation time (T2). The changes in signal intensities on T1 and T2 weighted images relate to very specific tissue characteristics. The pulse sequence parameter is one of the important factors in determining the contrast on magnetic resonance images. Commonly used to pulse sequences are T1 weighted and T2 weighted spin echo sequences [3].

MRI remains the preferred method for brain imaging owing to the fact that it is highly sensitive in detecting brain abnormalities during the early stage of disease. It also has excellent detection capabilities for brain tumors, cerebral infarction and other infections. In regard to brain magnetic resonance images T1 and T2 relaxation times play a very crucial role in determining signal intensity and contrast. There is a distinct differentiation of contrast on T1 and T2 weighted images. Similarly brain pathology also has some common signal characteristics. The type of pathology and its contrast in T1 and T2 weighted images is illustrated in form of the table 1 below.

 Table 1: Contrast and Pathology correlation in

MRI [3]		
	Contrast in	Contrast in
Pathology	T1 weighted	T2 weighted
	image	image
Solid mass	Dark	Bright
Fat	Bright	Dark
Cyst	Dark	Bright
Acute and chronic blood	Gray	Dark
Sub acute blood	Bright	Bright

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Some of the problems are common to both computed tomography and magnetic resonance medical images. These problems include partial volume effect, different kinds of artifacts like motion artifact, ring artifact etc., and noise due to sensors and related electronic systems. The typical artifacts that are present in magnetic resonance imaging systems include, Partial volume, RF noise, Intensity homogeneity, Gradient, Motion, Wrap around, Gibbs ringing and Susceptibility.

3. Computer Aided Diagnosis and Neuro Imaging

Typical in the issue automatic segmentation and classification of magnetic resonance images is the sheer volume of images themselves. Typically these magnetic resonance images are interpreted visually and examined by the radiologists and is highly subjective and time consuming. Shortage of radiologists compounded by the sheer volume of magnetic resonance images and very specifically the sensitivity of human eye in interpreting large number of images plays a very crucial role is the accurate classification of brain tumors. Invariably, there is decrease in sensitivity with increase in number of images when problem is more predominant and when only small number of slices are affected. Hence there is a huge need for automated systems that are capable of analyzing and classifying medical images.

These automated systems can be classified under the broad head of computer aided diagnosis (CAD) systems. Sometimes the term CAD also stands for computer aided detection systems. The term computer aided diagnosis (CAD) broadly encompasses the use of computer algorithms to aid in the process of image interpretation [4]. CAD is also now used in general to categorize and the extraction of computerize quantitative measurements from medical images.CAD system has become the most important research subject in the domain of medical imaging and diagnostic radiology.CAD systems act as a credible secondary opinion thereby improving the accuracy and the consistency of radiological diagnosis [5]. The CAD system has the ability to improve quality and productivity of radiologists. Current CAD systems are serving as complimentary tools that allow the radiologist's attention to certain area of image that need further evaluation [6]. Most of the time, these systems are not used for routine clinical evaluation. All these statements points to the fact that there is huge need for automated detection and classification of brain tumors. Similarly there is need to present this automation and detection procedures in the form of usable tool to the end user. The block diagram of the CAD tool illustrated in this research work is given in the figure 1.



Figure 1: Lay out of the CAD tool

4. Segmentation Approaches

Automatic segmentation of medical images is a difficult and complex task and the segmentation output is affected by partial volume effect, artifacts and closeness in the gray level of different soft tissues. There is no universal segmentation algorithm suitable for all medical images. The choice of the algorithm is influenced by the type of image, the reason for analysis and its possible use. A survey of literature reveals that the image segmentation techniques can be classified in to different types. Typically the image segmentation approaches falls under any one of the following categories [6].

1. Edge based segmentation

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- 2. Threshold based segmentation
- 3. Region based segmentation
- 4. Cluster based segmentation
- 5. Hybrid based segmentation

In the case of edge based segmentation the algorithms attempts to resolve the image by detecting the edges between different regions. These edges which are characterized by sudden changes in the intensity value are extracted and grouped to form closed region boundaries.

Threshold based segmentation is one of the oldest and most powerful techniques employed for segmenting different types of images. The fundamental idea in this approach is to use the threshold to divide the pixels based on the intensity value. Those pixels which are having higher intensity values than the threshold are grouped in to a particular class and those pixels which are having intensity values less than threshold are grouped in to a different class [7].

The region based methods attempted to segregate the images into different regions. These regions are categorized based on similarity or dissimilarity in regard to a set of predefined conditions [8].

Clustering is very versatile segmentation approach in which the image is categorized in to different clusters. The clusters are formed by predefining certain similarity conditions between the pixels [9]. Once these conditions are predefined similar pixels are identified and grouped to form different clusters. Clustering does not alter the intensity values of the images and are hence primarily suited for analysis of medical images. This is very much essential because of the fact medical images contain valuable clinical information embedded in the form of different shapes, structures, morphology and intensity. It is very much essential that image processing approaches do not alter these attributes and there by skewing the clinical information content in them.

The hybrid approaches [10] combined any two of the above methods and are typically influenced by the application to which they are proposed to be employed. These hybrid methods tend to exploit the advantages of those two methods and compensating for their inherent limitation.

In this work, three different segmentation methods are studied. These three methods include segmentation by K-means clustering, segmentation by Fuzzy C means clustering and Watershed segmentation [11]. The following section explains these three approaches in detail.

4.1 K -Means Clustering

The K-Means method can be categorized as numerical, unsupervised, non-deterministic and iterative approach that classifies the input data points into multiple classes based on their distance from one another. The algorithm assumes that the data features form a vector space and tries to find natural clustering in them [11]. K-Means employs least-squares partitioning method which dissects a collection of objects into K distinct groups. The algorithm iterates over these steps;

Compute the mean of each cluster.

- 1. Compute the distance of each point from each cluster by computing its distance from the corresponding cluster mean. Assign each point to the cluster it is nearest to.
- 2. Iterate over the above two steps till the sum of squared within group errors cannot be lowered any more.

The points are clustered around centroids, which are obtained by minimizing the objective from the equation 1:

$$V = \sum_{i=1}^{\kappa} \sum_{x_j \in S_i} \left(x_j - \mu_i \right)^2 \tag{1}$$

Where there are k clusters S_i , i=1, 2... k and μ_i is centroid or the mean point of all the points; $\mathbf{x}_i \in \mathbf{S}_i$.

The K means clustering processing can be described as below [11].

- Partitioning the dataset is into K clusters and the assigning data points randomly to create clusters that have roughly the same number of data points.
- For each point of data •
- Calculating the distance (Mahalanobis or

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Euclidean) between the data point and each cluster.

- If the data point is nearest to its own cluster, then leaving the data point where it move it into the closest cluster otherwise.
- Repeating the above step until there is no data point moving from one cluster to another and the clusters are stable to end the clustering process.
- The choice of initial partition influences hugely the result, in terms of inter-cluster and intra-cluster distances and cohesion.

The new centroid for each cluster is calculated using the equation 2

$$\mu_{i} \coloneqq \frac{\sum_{i=1}^{m} \mathbf{1} \{ C_{(i)} = j \} x^{(i)}}{\sum_{i=1}^{m} \mathbf{1} \{ C_{(j)} = j \}}$$
(2)

Where k is a parameter of the algorithm (the number of clusters to be found), *i* iterates over the all the intensities, *j* iterates over all the centroids and μ_i are the centroid intensities.

4.2 Fuzzy C-means Clustering (FCM)

Fuzzy clustering plays an important role in solving problems in the areas of pattern recognition and fuzzy model identification. A variety of fuzzy clustering methods have been proposed and most of them are based upon distance criteria [12]. One widely used algorithm is the fuzzy c-means (FCM) algorithm. It uses reciprocal distance to compute fuzzy weights. Fuzzy C-means Clustering (FCM), is also known as Fuzzy ISODATA, is an clustering technique which is separated from hard k-means that employs hard partitioning. The FCM employs fuzzy partitioning such that a data point can belong to all groups with different membership grades between 0 and 1. FCM is an iterative algorithm. The aim of FCM is to find cluster centers (centroids) that minimize a dissimilarity function. To accommodate the introduction of fuzzy partitioning, the membership matrix (U) is randomly initialized according to Equation 3

$$\sum_{i=1}^{c} u_{ij} = 1, \forall j = 1, \dots, n$$
(3)

The dissimilarity function which is used in FCM is given Equation 4

$$J(U, c_1, c_2, \dots, c_c) = \sum_{i=1}^{c} J_i = \sum_{i=1}^{c} \sum_{j=1}^{n} u_{ij}^{\ m} d_{ij}^{\ 2}$$
(4)

 u_{ij} is between 0 and 1; c_i is the centroid of cluster I; d_{ij} is the Euclidian distance between i_{th} centroid(c_i) and j_{th} data point; m $\in [1,\infty]$ is a weighting exponent.

To reach a minimum of dissimilarity function there are two conditions. These are given in Equation 5 and Equation 6.



Detailed algorithm of fuzzy c-means proposed by Bezdek in 1973[13]. This algorithm determines the following steps [14].

Step 1: Randomly initialize the membership matrix (U) that has constraints in Equation 3.

Step 2: Calculate centroids (c_i) by using Equation 5.

Step 3: Compute dissimilarity between centroids and data points using equation 4. Stop if its improvement over previous iteration is below a threshold.

Step 4: Compute a new U using Equation 6. Go to Step 2.

By iteratively updating the cluster centers and the membership grades for each data point, FCM iteratively moves the cluster centers to the "right" location within a data set.

4.3 Watershed Segmentation

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The concept of watershed is based on visualizing an image in three dimensions: two spatial coordinates and intensity [15]. We consider three types of points:

- 1. The points belonging to the local minimum.
- 2. The points where a drop of water, if placed at the locations of these points, would fall to a single local minimum. It is called *catchment basin* or *watershed*.
- 3. The points where water would be equally likely to fall to more than one local minimum. They are similar to the crest lines on the topographic surface and are termed *divide lines* or *watershed lines*.

The two main properties of watershed segmentation result are continuous boundaries and oversegmentations. As we know, the boundaries that made by the watershed algorithm are exact the watershed lines in the image. Therefore, the numbers of region basically will be equal to the numbers of minima in the image. There are two steps to achieve the solution using marker:

- 1. Preprocessing
- 2. Defining the criteria that the markers have to be satisfied.

The following figures are the mechanism to construct dam.



Supposed that figure 2 is the image of input, and the height of the "mountain" is proportional to intensity values input image. We start to flood water from below by letting water rise through the holes at a uniform rate. Figure (b) we see that water now has risen into the first and second catchment basins. So we will construct a dam to stop it to overflowing, and do the same motion step by step. Direct application of the watershed segmentation algorithm in the form discussed in the previous section generally leads to over segmentation due to noise and other local irregularities of gradient. An approach used to control over segmentation is based on the concept of markers [15]. We have internal markers, associated with objects of interest, and external markers. A procedure for markers selection typically will consist of two principal steps: (1) preprocessing (usually smoothing) (2) definition of a set of criteria that markers must satisfy. (to do edge detection for every small region).

5. The proposed CAD Tool

A comprehensive tool capable of performing segmentation and different analysis as required by the user is designed. The tool is proposed to be in the form of a Graphical User Interface (GUI) which enables the user to have ease of operation in loading the image, segmenting it and analyzing it. The tool is coded using Matlab Version 12 .A Graphical User Interface enable the user to have seamless use and flexibility of operation. The implementation is carried out in a system having Core 2 Duo processor cloaking at a speed of 2 GHz with a RAM of 2GB. The screen shot of the tool is given in the figure 3.



Figure 3: Screenshot of the CAD Tool

Input / Output section of the tool. The tool is capable of handling images in normal image formats like, .jpg, .bmp, .tiff and also it is capable of handling DICOM images. Using the tool a series of DICOM images can also be fed as input for 3D Visualization. In the output section, function elements here enable to save the image in current display window for further analysis. The output section also has the capability to save 3D volume information in the case of series images being read.

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Initial Analysis: This includes, Histogram Analysis, Pixel Profile of a particular region of the image and a specific tool for adjusting the image intensity for better visualization.

Basic Processing: This incorporates analysis like, Image adjusts for smoothening, histogram equalization, and wiener smoothening and morphology based analysis.

Color Adjustment: This has the option of viewing the image in different color spaces like, hot, gray and jet. This helps in better visualization of images.

Edge Detection: Different edge detection operations like, Prewitt, Sobel, Canny, Log, Roberts and Zero crossing operators are implemented for edge analysis.

In the segmentation section the segmentation, quantification and evaluation of segmentation is carried out. K means segmentation, Watershed segmentation; Fuzzy c means segmentation have been implemented here.

some of the important functions of the tools and methods used in this CAD tool are illustrated in this section.

Histogram analysis

Histogram analysis gives a crucial indication of the representation of the pixels which intirn can help in the visulisation of the segemntation. It can be observed from the figure 4 in the unsegemnted images pixels are distyibuted across the spectrum.



Figure 4 : Input Brain MRI and its Histogram Figure 5 gives an insight in to level of segmenation and it can be observed that the histogrma represents pixel profile concentrated in a partcilaur region unlike in the case of unsegemented image



Figure 5: Segmented Brain tumor and its Histogram.

Intensity profile

Intensity profile anlysis is another usefull indication about the qaulity of segemntation. It can be observed from the figure (6) when the instensity profile is calcualted across the tumor in unsegemnted image, it represents the variation of the pixel value across different intensity values. It can also be observed that pixel representation across the tumor in segemnted iamge is discrete and the intensity profile is accumluated in a partcilaur region.



Figure 6 : Intensity Profile across tumor, Pre and

Post segmentation

Manual visual interpretation

Manual visual interpretation and analysis also play a very critical role in the evlaution procedure, the adjust intensity range tool helps in manual adjustement of the threshold value there by providing better visualisation as illustarted in the screen shot presented in the figure 7.

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Figure 7: Adjust intensity tool in action *Morphological image processing*

Morphological image processing pursues the goals of removing these imperfections by accounting for the form and structure of the image. Morphological image processing is a collection of non-linear operations related to the shape or morphology of features in an image. Morphological operations rely only on the relative ordering of pixel values, not on their numerical values, and therefore are especially suited to the processing of binary images. The figure 8 illustrates the results of morphological operations which resulted in obtaining the image gradient, the foreground of the image and reconstruction of the image.



Figure 8: Image Gradient, Foreground, Reconstructed image using morphology operations *Colormaps*

The human brain perceives changes in the lightness parameter as changes in the data much better than, for example, changes in hue. Therefore, colormaps which have monotonically increasing lightness through the colormap will be better interpreted by the viewer. Different color space images representation is presented in the figure 9.



Figure 9: Hot, Jet and Gray color space images *Edge detection*

Edge detection plays a crucial role in identifying individual elements in an image. Detection of edges in an image is a very important step towards understanding image features. Edges consist of meaningful features and contained significant information. The figures 10 & 11 describe the edges obtained using different operators.



Figure 10: Edges as obtained by Canny, Sobel and Zero Cross operators

It can be observed from the figure, the performance varies between operators, while operators like Canny, Prewitt and Robert are capable of clearly demarcating edges other operators do not have a very clear cut demarcation of edges.



Figure 11: Edges as obtained by Prewitt, Robert and Log operators

Segmentation

As a part of this tool three different segmentation methods are incorporated for segmentation of Brain MRI images. These methods include, K

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means segmentation, Watershed segmentation, Fuzzy c means segmentation. The results of these segmentation approaches are illustrated in the figure 12





Figure 12: Segmented Brain Tumor using K means, Water shed and FCM **6.Conclusion**

In this work the authors have presented a CAD system that can be used in the analysis of Brain MR Images. The tool has different features that can help in having differential diagnosis. The CAD tool has functional regions for basic analysis primary analysis and classification of segmented These functional tumor. tools provide a comprehensive scope for different kind of image analysis. Histogram analysis is one of the most prominent approaches for image processing and analysis. The CAD tool has an option for performing and visualizing histogram of a particular image under analysis. The histogram helps in understanding the intensity distribution and can serve as a pointer towards the quality of segmentation. The intensity adjustment tool also helps in better visualization of the image with the user controlling the threshold for segmentation. This option enables better visualization and perception. This function can be of great help in having a manual segmentation and analysis approach. Similarly the users selected image profiling can be of great help in understanding the distribution of pixels. This function empowers the user to choose the region or more specifically on which row or column the analysis has to be carried out. This feature is very specifically helpful in identifying the distribution of tumors or degree of scattered intensities along a particular axis. This kind of analysis proceeds simple information about different region in the segmented and the

original image. This will be of great help in segmenting and profiling different sections of an image. The same tool can also help in identifying artifacts and other types of noises. Similarly, the morphological furs can aid a radiologist by accounting for the form and structure of an image. These morphological illustrations have huge clinical significance and provide valuable pointers for diagnosis. Edge analysis is of great help in identification and demarcation. Different edge operations are implemented and studied in this research work. Of the different operations studied, it is observed the performance of canny & prewitt operators in comparatively better than other operators. The edge analysis for can be used to clearly demarcate the tumors and the contours of that particular tumor as identified by edge detection operator can provide vital information about its morphology. The color adjustment helps visualization, interpretation in better and perception of an image. The visualization of image in different color space can help in better understanding and analysis.

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